

**Before the
Federal Communications Commission
Washington, D.C. 20554**

In Re Measurement Standards for Digital)	
Television Signals Pursuant to the Satellite)	ET Docket No. 06-94
Home Viewer Extension and Reauthorization)	
Act)	

**Engineering Statement of
Meintel, Sgrignoli, & Wallace
Concerning Measurement
Of Digital Television Reception**

1. At the request of the National Association of Broadcasters, the ABC, CBS, and NBC Affiliate Associations, and the Association for Maximum Service Television ("MSTV"), the undersigned have prepared this engineering statement for consideration by the Commission in connection with its Notice of Proposed Rulemaking in this proceeding. The credentials and experience of the undersigned are set forth in **Exhibit E**. As detailed there, we have, among other things, conducted thousands of digital signal intensity tests in a variety of locations around the United States; helped to design and test state-of-the-art digital receivers; and developed industry-standard computer-based analysis applications and specialized software concerning RF propagation. We attempt in this Engineering Statement to provide the Commission with the benefit of this experience. We begin with a short discussion of pertinent background facts, before addressing the specific issues raised by the Commission.

INTRODUCTION AND BACKGROUND

**Technical Standards for Determining Eligibility of Satellite-Delivered Network Signals
Pursuant to the Satellite Home Viewer Extension and Reauthorization Act**

2. In December 2004, Congress enacted the Satellite Home Viewer Extension and Reauthorization Act ("SHVERA"). In Section 204 of SHVERA, Congress directed the

Commission to conduct an Inquiry into whether the Commission should revise its digital television field strength and signal measurement procedures used to identify if a household is “unserved” for the purposes of the satellite copyright license for distant network signals. After soliciting comments from interested parties, on December 8, 2005, the Commission issued its SHVERA Report to Congress. In that Report, the Commission determined that no changes were needed to the digital television field strength *standards* or digital television *planning factors* for purposes of determining whether households are eligible to receive distant network signals. Left for this proceeding, however, was the task of crafting specific *procedures* for measuring the field strength of digital television signals at individual locations.

The Commission’s Implementation of Measurement Standards for Digital Television Should Be Based on Its Existing, Proven Methods for Measuring Analog Signals

3. In 47 C.F.R. § 73.686(d), the Commission prescribes specific *procedures* for measuring analog TV signals at particular locations. As the Commission has correctly concluded, the new digital TV measurement procedures should be based on these proven methods. Only slight variations from these standardized procedures are required to adapt the analog rules and apply them to digital TV measurements. These rules rely on common engineering protocols used worldwide for verifying coverage, determining transmit antenna radiation patterns, and developing propagation algorithms used in planning for allocation of broadcast station spectrum. With certain minor adjustments, the procedures set forth in Section 73.686(d) will work well for measuring *digital* signal strength.

**The Commission Should Specify the Use of a
Gain Antenna for Digital Television Measurements**

4. Based on our experience in conducting digital television measurements, and for the reasons outlined below, we recommend that the Commission require the use of a gain antenna for digital TV measurements. There are several reasons the Commission should require a gain antenna rather than a simple dipole antenna.

5. A simple dipole antenna with a known “K” Factor will provide accurate field strength measurements under most circumstances. However, a simple dipole antenna is susceptible to impaired signals from multipath or other interfering signals. Due to its non-directional nature, this antenna will not offer any discrimination of unwanted signals (such as multipath or interference from other television signals) even when properly oriented towards the desired digital television station. Further, given its non-directional nature, it does not comply with the Commissions assumptions for front-to-back ratio as used in the Planning Factors.

6. The Commission properly concluded in its SHVERA Inquiry that the Commission’s digital TV planning factors are sufficient for the purposes of SHVERA eligibility determination. Those factors are based on the use of a directional, gain antenna. The Commission should therefore rely on those same assumptions when making digital TV signal measurements.

7. The increased signal level from a gain antenna allows flexibility for the tester to use a variety of measurement instruments. Conversely, however, use of a dipole antenna limits the sensitivity of certain measurement instruments to a signal level greater than 41dB μ V/m in making digital TV signal measurements – which would make those instruments unusable for SHVERA measurements, and thus limit the tester’s equipment options.

8. The required minimum signal level at the input to measurement test equipment depends on the noise floor of that instrument. Some types of commonly-available measurement equipment, such as spectrum analyzers, require the signal to be measured to be 7 or 8 dB above its noise floor to accurately determine the signal level. (A lower margin value can be used, but only if sophisticated noise subtraction methods are employed by the user or the test equipment.)

9. In the analysis of a spectrum analyzer in Appendix B, the equivalent noise floor of the instrument is limited to -67 dBm/6 MHz. Considering the loss of the shielded downlead coaxial cable and the dipole conversion factor for a half-wave dipole antenna, the minimum measurable field strength in this setup is far above the FCC's required value (*e.g.*, 41 dB μ V/m for UHF). Therefore, more gain in the front-end circuitry is required to overcome the instrument noise floor. This gain can come from a higher gain directional antenna, a low-noise RF preamplifier, or both. Depending on the particular measurement equipment, both techniques may be required, as they each provide a larger input signal to the measurement equipment to overcome its noise floor. In many instances, however, use of a gain antenna alone will allow a spectrum analyzer to be used to measure signals as low as 41 dB μ V/m.

A Gain Antenna Is Less Costly for Testers to Acquire

10. Costs for a NIST Traceable Calibrated Dipole antenna range from \$1,300 to \$2,100 from various manufacturers. By eliminating the need for a calibrated dipole antenna, the Commission can significantly reduce the costs of the equipment needed by testers. The list price, for example, of the Scala/Kathrein CL-1469 Log Periodic antenna is \$468, only a fraction of that for the calibrated dipole antenna. The Scala CL-1469, due to its log-periodic design, provides a reasonably flat gain characteristic of about 8 dB across the UHF television band. Calibration of the actual gain antenna utilized in field testing could be conducted by the antenna

manufacturer, thus eliminating the need for tester to purchase a costly calibrated dipole. Some manufacturers can provide a calibrated gain antenna that has been calibrated against a known dipole or NIST traceable antenna. As an alternative, an antenna manufacturer might provide a *certified* antenna chart that certifies the gain of the antenna at specific channels. In these ways, a tester can eliminate the need for a costly NIST traceable Dipole antenna.

A Gain Antenna Does Not Require Adjustment for Each Channel Measured

11. With a dipole, measuring each channel requires precise adjustment of the length of the antenna elements – and hence creates the risk of tester error. Since a tester will typically be testing four (and sometimes more) different stations at a single home, use of a gain antenna eliminates the need for repeated adjustments of the antenna during a site visit. The tester would have two unattractive choices: moving the dipole (adjusted for a specific channel) to five different locations, then doing the same for each other station to be tested; or adjusting the dipole elements repeatedly at each testing location for measuring different channels. Use of a gain antenna eliminates these burdens.

A Gain Antenna is More Robust and Less Likely to be damaged

12. As a practical matter, a gain antenna is more robust than a dipole. A more rugged antenna will last longer and require fewer replacements due to minor mishaps than a fragile dipole antenna.

Digital Television Measurement Procedures

Cluster Measurements Provide a Reasonable Basis for Median Field Strength

13. In its NPRM, the Commission asks for comments about the procedures to be used in measuring digital TV signals. We concur with the Commission's conclusion that a cluster of five measurement locations spaced approximately 3 meters apart provides a practical means of

deriving a median field strength value for a given location. As this method is currently required by the analog rules, testers are familiar with the procedure and can easily use it in making digital signal measurements.

Measurement of the Integrated 6 MHz Band Power Is the Only Accurate Measurement

14. Based on our experience, we concur with the Commission's conclusion in the NPRM that the digital TV signal power should be measured as the integrated power over the 6 MHz channel bandwidth of the digital TV signal. Measurements of digital TV signals using other techniques have proven, in our experience, to be inaccurate. Measurements of the DTV pilot signal is unacceptable due to the possible impairments of multipath or other phenomenon that would yield incorrect results of the integrated 6 MHz band power. These methods are clearly inaccurate in our view, and there is little justification for their use given the wide availability of economical and accurate instruments that provide correct band power measurements.

DTV Measurement Instruments

15. Many commercially available instruments are available in the marketplace that will provide measurements using the methodology the Commission proposes (with our minor suggested amendments). Several spectrum analyzer manufacturers (such as Rohde & Schwarz and Agilent) provide units that will measure the integrated power over the user-selectable band-power marker bandwidth. These instruments are commercially available with different options available from the manufacturers. The handheld Rhode & Schwarz Model FSH-3 costs about \$7,000 -- a very reasonable price when compared with that of analog television field strength meters such as the Potomac FIM-72A, which costs over \$14,000. A higher quality, mid-range

Agilent E4402B portable spectrum analyzer costs \$16,000 and can be rack-mounted in a field truck.

16. In addition, field strength meters available from Z-Technology, such as the Model RF-507, will provide a measurement of the integrated 6 MHz band power for digital television signals. This instrument may have been used by some testers for analog TV signals or FM signals, and is also usable for digital television signals. The list price for the RF-507 meter is \$12,000. In the case of the RF-507, measurements are made of individual smaller power bands and these individual power measurements are then summed to achieve the 6MHz band power. Comparisons of this instrument to spectrum analyzers with band-power markers have shown a good correlation of accuracy, typically within +/- 1 dB.

17. As demonstrated here, the costs for measurement instruments for digital TV signals are comparable to, and in some cases less than, high quality analog TV signal level meters. Using accurate and high quality measurement instruments thus does not create an undue financial burden on the tester. **We recommend that the Commission bar the use of field strength or field intensity meters that do *not* provide a reading of total in-band average power or integrated power over the 6 MHz channel. Older analog meters that use diode detectors with very narrow IF Bandwidths for use with NTSC television are wholly unacceptable for digital television measurements. And measurements on spectrum analyzers utilizing narrow-band markers are also inaccurate for the measurement of digital TV signals.** The narrow-band markers fail to account for the total 6 MHz average band-power and will not accurately compensate for channels that are impaired by multipath or tilted pass band responses.

IF Bandwidth for DTV Measurement Equipment

18. We recommend that the Commission require an IF Bandwidth of less than 100 kHz. The Commission has proposed in its NPRM that the measurement instrument used should have an IF Bandwidth of no greater than 6 MHz. All of the instruments cited above (swept-tuned devices) have IF bandwidths significantly lower than 6 MHz. In fact, most instruments in use today have IF Bandwidths *below 100 kHz*. We respectfully suggest that the Commission require a maximum IF Bandwidth that more closely matches those of instruments in use today; a maximum IF Bandwidth of no greater than 100 kHz might well be suitable. We note that an instrument with a 6 MHz IF Bandwidth might be subject to inaccurate results when measuring a digital TV signal with an occupied adjacent channel: the signal in the adjacent channel may cause the instrument to read an incorrect power due to “spillage” from the undesired adjacent channel into the desired channel. In this case, a household might be determined to be served when a better instrument would show that the household is in fact unserved.

19. We surmise that a 6MHz IF Bandwidth instrument design might be a thermal power meter with a well-defined 6 MHz band pass filter inserted in front of the thermal detector or a “fixed-tuned” receiver with a calibrated signal meter. This type of test setup would require the tester to acquire fixed band pass filters for each channel to be tested and require a separate “fixed-tuned” receiver for each channel to be tested. Both the extreme complexity of this setup and its likely inaccuracy make it a highly undesirable choice. Thus, we recommend that the Commission adopt an IF Bandwidth limit of no greater than 100 kHz.

Coaxial Transmission Lines and Attenuation

20. We recommend that the Commission require the use of shielded coaxial transmission lines from the antenna to the measurement instrument. This will minimize the ingress of unwanted signals into the measurement instrument. When coaxial cable is used, a suitable balun should be required. The Commission should discourage the use of “twin-lead” for these measurements, as this type of transmission line is susceptible to ingress of unwanted signals, is somewhat unstable in terms of impedance, and is not generally in common use today. Consumer antennas that have twin-lead feed-points are generally provided with a balun to match the antenna to a 75 ohm coaxial line. Thus, it is reasonable to assume that in most cases, consumer equipment of current production will be of the coaxial type.

21. The Commission’s Planning Factors for digital TV, as set forth in OET Bulletin 69, assume a coaxial transmission line. It is reasonable to carry this assumption forward to digital TV measurements.

22. We agree with the Commission’s proposal that the antenna impedance be matched to the transmission line at all frequencies measured. And we further suggest that by using appropriate baluns, the transmission line impedance also be matched to the input impedance of the measurement instrument at all frequencies measured.

23. To obtain accurate results, it is imperative that the line loss of the transmission line between the antenna and the measurement instrument be accurately accounted for in the calculation of the field strength. The transmission line loss should be measured for each of the frequencies tested.

Receive Antenna Polarization

24. The Commission should require use of a horizontally-polarized antenna. Since all rules regarding station Effective Radiated Power (ERP) and power limits are given in the horizontal polarity, measurements of digital TV signals should use similarly polarized antennas. Using vertically-polarized antennas would unfairly penalize stations that are transmitting only in the horizontal plane. Cross-polarization isolation on the order of up to 15 dB could easily result in vastly inaccurate results if testers were to use vertically polarized antennas. Thus, we urge the Commission to require use of a horizontally-polarized receive antenna.

Receive Antenna Orientation

25. As the Commission correctly concluded in the SHVERA Inquiry, the receive antenna should be properly oriented toward the strongest signal from the transmitter being tested. In addition, the antenna should be properly oriented for each station to be measured. This is consistent with good engineering practice. As noted in the NAB comments in the SHVERA Inquiry, the assumption of a properly oriented roof-top antenna was the basis of all the DTV planning and spectrum allocation proceedings before the Commission. To change these assumptions at this late date would be incongruous with the Commission's implementation of the digital transition and would punish TV stations that have done exactly what the Commission has asked them to do.

Measurement Antenna Height

26. We concur with the Commission's proposal in the NPRM to adopt the antenna measurements heights used in the current analog rules. The Commission's planning factors for digital TV utilize a receive antenna height of 9.1 meters (30 feet), and we concur that using this height for homes that are two or more stories is appropriate in the SHVERA context, while

allowing a lower 6.1 meter (20 feet) antenna height for homes that are one story. This allows flexibility to accommodate homeowners that do not have a second story, while implementing the statutory assumption that the receive antenna be roof-mounted.

Weather Considerations

27. It is reasonable for the Commission to adopt the current analog rules concerning weather conditions at the time of the measurement. Digital TV signal strengths are more accurately measured when weather conditions are stable, inclement weather is not present, and weather front movements are not present in the measurement area. In addition, the Commission should require that digital TV measurements be taken during periods with no precipitation. Based on our field experience, large fluctuations can occur in the field strength of UHF signals when rapid changes in temperature occur. This phenomenon is usually associated with a weather front movement.

Data Recording

28. We recommend that the Commission require testers to follow standardized data recording methods. Keeping the measurements in units of dB μ V/m (often abbreviated as dBu) is consistent with the Commissions digital field strength standards. Further, the tester should keep accurate records of each test. These records should include, at a minimum, the following:

(A) A list of calibrated equipment used in the field strength survey, which for each instrument specifies the manufacturer, type, serial number and rated accuracy, and the date of the most recent calibration by the manufacturer or by a laboratory. Include complete details of any instrument not of standard manufacture.

(B) A detailed description of the calibration of the measuring equipment, including spectrum analyzers, amplifiers, connecting cables, baluns, and receive antenna.

(C) For each measurement location, all factors which may affect the recorded field strength, such as topography, antenna height, weather, and other information.

(D) A description of where the cluster measurements were made.

(E) Time and date of the measurements and signature of the person making the measurements.

(F) For each channel being measured, a list of the measured values of field strength (in units of dB μ V/m after adjustment for line loss and antenna factor) of the five readings made during the cluster measurement process, with the median value highlighted.

Tester Availability

29. The Commission seeks comment on the availability of qualified independent testers to perform digital field strength measurements. We believe that by providing the necessary procedures and spreadsheet templates for use by Testers, we can help address those concerns. As the Commission may be aware, our firm has provided training to the industry on digital TV transmission systems. In fact, some of these seminars have been held at FCC facilities. Our purpose with these educational seminars is, among other things, to train potential testers on the correct methods for digital TV field strength measurements. We have provided, as an **Appendix D** to this Statement, a written procedure that can be utilized by any properly-trained tester for making digital TV field strength measurements in compliance with the Commission's proposed rules. We respectfully suggest that, by providing a detailed "cookbook" of this type to the public through a Public Notice or an OET Bulletin, the Commission can provide ready access to the proper measurement techniques and calculations without requiring testers to research the text of the Rules. In addition, we can provide the Commission with a copy of an Excel Spreadsheet Template that allows a tester to complete the measurements using the instruments described here and easily convert these to Median Field Strength, without the need for complex formulas and development of their own spreadsheet. We believe that these measures will substantially reduce the *perceived* complexity of the measurement procedures and allow access to a larger pool of testers.

Conclusions

31. As the Commission properly concluded in the SHVERA Inquiry, the current analog rules in 47 C.F.R. § 73.686 (d) provide a sound basis upon which to craft the new digital television measurement rules. With a few minor modifications, the current analog rules can be applied to measurement of DTV signals. These modifications, although minor in scope, are extremely important to ensuring accurate, reliable, and repeatable results when making digital television signal measurements. The Commission has properly considered many of the important modifications to the rules to make them applicable to digital television. We urge the Commission to adopt our modest additional proposed adjustments.

Respectfully Submitted:

/s/

William Meintel

/s/

Gary Sgrignoli

/s/

Dennis Wallace

Appendix A

SUGGESTED METHODOLOGY FOR DTV FIELD STRENGTH MEASUREMENTS

Collection of field strength data to determine digital television signal intensity at an individual location—cluster measurements:

(1) Preparation for measurements

(i) Testing antenna. The test antenna shall be a *gain* antenna, provided its antenna factor for the channel(s) under test has been determined. Use the antenna factor supplied by the antenna manufacturer as determined on an antenna range.

(ii) Testing locations. At the location, choose a *minimum* of five locations as close as possible to the specific site where the site's receiving antenna is located. If there is no receiving antenna at the site, choose a minimum of five locations as close as possible to a reasonable and likely spot for the antenna. The locations shall be at least three meters apart, enough so that the testing is practical. If possible, the first testing point should be chosen as the center point of a square whose corners are the four other locations. Calculate the *median* of the five measurements (in units of dBuV/m) and report it as the measurement result.

(iii) Multiple signals. If more than one signal is being measured (*i.e.*, signals from different transmitters), use the *same* locations to measure each signal.

(2) Measurement procedure. Measurements shall be made in accordance with good engineering practice and in accordance with this section of the Rules. At each measuring location, the following procedure shall be employed:

(i) Testing equipment. Measure the field strength (root-mean-square over a 6 MHz bandwidth) of the DTV signal with a calibrated spectrum analyzer with an intermediate frequency (i.f.) bandwidth of between 10 kHz and 30 kHz. Perform an on-site calibration of the measurement instrument in accordance with the manufacturer's specifications. The instrument must accurately indicate the root-mean square of the signal voltage in a 6 MHz bandwidth. Take all measurements with a horizontally-polarized receive antenna. Use a shielded coaxial transmission line between the testing antenna and the measurement equipment. Match the antenna impedance to the transmission line at all frequencies measured, and employ a suitable balun between the antenna and the unbalanced line. Take account of the transmission line loss for each channel (center) frequency being measured.

(ii) Weather. Do not take measurements in inclement weather or when major weather fronts are moving through the measurement area.

(iii) Antenna elevation. When field strength is being measured for a one-story building, elevate the testing antenna to 6.1 meters (20 feet) above the ground. In situations where

the field strength is being measured for a building taller than one-story, elevate the testing antenna 9.1 meters (30 feet) above the ground.

(iv) Antenna orientation. Orient the testing antenna in the direction which maximizes the value of field strength of the signal being measured. If more than one station's signal is being measured, orient the testing antenna separately for each station.

(3) Documentation: Written record shall be made, and shall include at least the following:

(i) A list of *calibrated* equipment used in the field strength survey, which for each instrument specifies the manufacturer, type, serial number and rated accuracy, and the date of the most recent calibration by the manufacturer or by a laboratory. Include complete details of any instrument not of standard manufacture.

(ii) A detailed description of the *calibration* of the measuring equipment, including spectrum analyzers, amplifiers, connecting cables, baluns, and receive antenna.

(iii) For each spot at the measuring site, all factors which may affect the recorded field strength, such as topography, antenna height, as well as types of vegetation, buildings, obstacles, weather, and other local features.

(iv) A description of where the cluster measurements were made.

(v) Time and date of the measurements and signature of the person making the measurements.

(vi) For each channel being measured, a list of the measured values of field strength (in units of dBu and after adjustment for line loss and antenna factor) of the five readings made during the cluster measurement process, with the median value *highlighted*.

APPENDIX B:

SUGGESTED EQUIPMENT LIST FOR DTV FIELD STRENGTH DETERMINATION

The following list is an *example* of the test equipment required to determine DTV field strength at a given test site location. Other manufacturers can be utilized that will meet the following specifications as well. The preferred set of equipment would use a calibrated directional antenna (with gain), well-shielded low-loss coaxial cable, a robust low-noise figure amplifier, and a spectrum analyzer with channel power measurement capability.

Equipment	Parameter	Value	Units	Make/Model	Spec	Price
Calibrated Antenna	Gain over a dipole (directivity)	≥ 6	dBd	Scala CL-1469B	8 dBd	\$ 468
	Total Beamwidth (- 3 dB)	≤ 60	degrees		52°	
	Front-to-back ratio	≥ 15	dB		> 35 dB	
	Impedance	50	Ω		50 Ω	
Coaxial Cable	Length	≥ 50	feet	Belden-CDT RG223	50 feet	\$ 125
	Impedance	50	Ohms		50 Ω	
	Loss	≤ 6	dB/50'		4.4 dB/50'	
	Shields	≥ 2	*		2 (braid & foil)	
Antenna Preamplifier	Broadband gain	≥ 20	dB	Mini Circuits ZFL-1000H	28 dB	\$ 230
	Noise Figure	≤ 5	dB		5 dB	
	Input & Output Impedance	50	Ω		50 Ω	
	3 rd Order Intermod (IP3)	$\geq +33$	dBm		+33 dBm	
Spectrum Analyzer	Frequency range	50 - 800	MHz	Rohde & Schwarz FSH-3	0.05 – 3 GHz	\$ 7,000
	Channel Power Markers	---	*			
	Impedance	50	Ohms			
	DANL	< -67.6	dBm/6 MHz			
	Tracking generator <i>option</i>	---	*			\$
	Preamplifier <i>option</i>	---	*			\$

APPENDIX C:

BACKGROUND INFORMATION FOR FIELD STRENGTH DETERMINATION METHODOLOGY

Figure 1 contains the block diagram of the DTV field strength equipment setup that is used in the following background information.

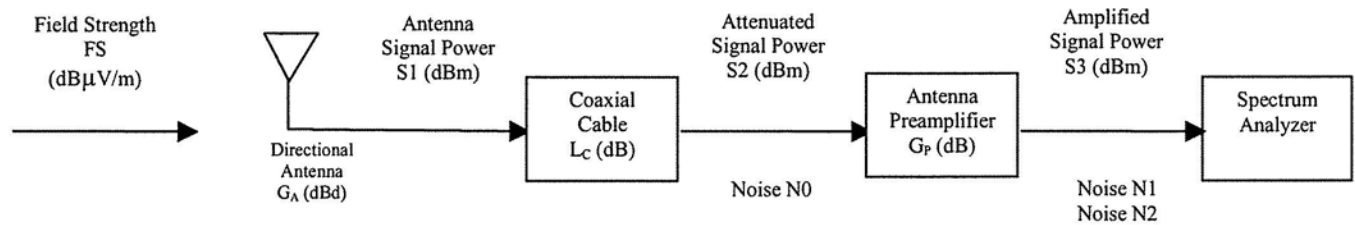


Figure 1 DTV Field Strength Measurement Setup

Field strength at the input to the antenna can be calculated by simply measuring the average DTV power in 6 MHz with the spectrum analyzer and then applying some simple algebra to this power value. The algebra is explained below.

The minimum signal that can be measured at the spectrum analyzer input is limited by the *equivalent* noise floor that exists at its input. In **Figure 1**, there are two noise sources to consider.

The first noise floor, denoted by N1 in **Figure 1**, is due to the analyzer itself and can be determined from the spectrum analyzer specs or by direct measurement. From its specification sheet, the FSH-3 has a *typical* Displayed Average Noise Level (DANL) of -114 dBm when the 1 kHz resolution bandwidth (RBW) filter is used. That is,

$$N1 = \text{DANL} = -114 \text{ dBm} / 1 \text{ kHz RBW}$$

The equivalent noise bandwidth (NBW) of most spectrum analyzer resolution bandwidth filters is 1.1 times the RBW value (which is often described by its half-power, or 3-dB, bandwidth). That is,

$$\text{NBW} = 1.1 * \text{RBW}$$

For flat spectrum noise (which accurately describes the spectrum analyzer's noise floor over a 6 MHz channel bandwidth), the equivalent white noise power in 6 MHz is larger than this 1-kHz value by an amount determined by adding a correction factor (CF) as follows:

$$CF = 10 \cdot \text{LOG} [6 \text{ MHz} / \text{NBW}] = 10 \cdot \text{LOG} [6 \text{ MHz} / (1.1 \cdot \text{RBW})] = 10 \cdot \text{LOG} [6 \text{ MHz} / (1.1 \cdot 1 \text{ kHz})] = 37.4 \text{ dB}.$$

This means that the equivalent noise floor (N1) of this particular spectrum analyzer is:

$$N1 = -114 \text{ dBm/1 kHz} + 37.4 \text{ dB} = -76.6 \text{ dBm/6 MHz}.$$

The second noise source in **Figure 1** is from the antenna preamplifier. It also has an equivalent noise floor at its input. For the example above that uses the ZFL-1000H with a 28 dB gain (G_P) and a 5 dB noise figure (NF), this input noise power (N0) can be described as:

$$N0 = kTB + NF = -106.2 \text{ dBm/6 MHz} + 5 \text{ dB} = -101.2 \text{ dBm/6 MHz}$$

where k is Boltzman's constant, T is the temperature (often taken as room temperature of 25 degrees Celsius or 298 degrees Kelvin), and B is the bandwidth, which is always 6 MHz for the North American television system.

This equivalent noise floor at the preamplifier input is then increased in level by the gain (G_P) of the preamplifier. In the example above, there is a second noise floor at the input of the spectrum analyzer that can be determined as follows:

$$N2 = N0 + G_P = -101.2 \text{ dBm/6 MHz} + 28 \text{ dB} = -73.2 \text{ dBm/6 MHz}$$

Since both noise sources are different white Gaussian noise signals, they are statistically independent of each other (i.e., uncorrelated). This means that their noise powers can be added together linearly (i.e., in Watts, not in dBm), and then the sum can be put back into the logarithmic domain. That is,

$$N_{\text{TOTAL}} = 10 \cdot \text{LOG} [10^{(N1/10)} + 10^{(N2/10)}] = 10 \cdot \text{LOG} (10^{(-76.6/10)} + 10^{(-73.2/10)}) = -71.6 \text{ dBm/6 MHz}$$

This is the total equivalent noise power at the input to the spectrum analyzer, and determines the minimum DTV signal that can be measured by the analyzer.

The minimum average DTV signal power must be at least equal to this noise power level to be measured accurately, assuming the user performs a calculation that subtracts this known noise level. To avoid the need for this noise correction calculation, the average DTV signal power must be at least 10 dB above the noise floor in order to limit the error caused by the analyzer input noise floor to be less than 0.5 dB. That is,

$$S3(\text{min}) = N_{\text{TOTAL}} + 10 \text{ dB} = -71.6 \text{ dBm/6 MHz} + 10 \text{ dB} = -61.6 \text{ dBm/6 MHz}$$

This minimum DTV signal level at the spectrum analyzer input is also the same level that exists at the preamplifier output (assuming a very short cable with insignificant loss is used between

the preamplifier and the spectrum analyzer). This means that the preamplifier DTV input level is lower than its output level by the amount of amplifier gain (G_P). That is,

$$S2(\text{min}) = S3(\text{min}) - G_P = -61.6 \text{ dBm/6 MHz} - 28 = -89.6 \text{ dBm/6 MHz}$$

However, at the input to the download coaxial cable, the signal is larger by the amount of cable loss (L_C). That is,

$$S1(\text{min}) = S2(\text{min}) + L_C = -89.6 \text{ dBm/6 MHz} + 5 \text{ dB} = -84.6 \text{ dBm/6 MHz}$$

The DTV signal level at the input of the coaxial cable is also the signal level at the output of the directional antenna. The DTV signal power at this point must be transformed into an electromagnetic field strength that exists in the ether at the antenna input. To determine the field strength, a two-step process must be considered: conversion between signal power and signal voltage as well as conversion between signal voltage and signal field strength.

The first process to consider is conversion between power and voltage. A logarithmic conversion factor can be obtained by applying the well-known power equation (V^2/R) in the following formula:

$$K_{VP} = 10 \cdot \text{LOG}[(1 \mu\text{V})^2 / (50 \Omega \cdot 1 \text{ mW})] = -107.0 \text{ dBm-dB}\mu\text{V}$$

This result allows one to take a voltage (in dB μ V) in a 50-Ohm system and subtract 107 to get its power value (in dBm). Likewise, one can take a power value (in dBm) and add 107 to obtain its voltage (in dB μ V) in a 50-Ohm system.

The second process is the conversion of field strength (E , in dB μ V/m) and voltage (V , in dB μ V) for a matched (i.e., terminated in its characteristic impedance) half-wave dipole antenna. The formula is quite simple, as follows:

$$V = E \cdot \lambda / (2 \pi) = E \cdot [c / (2 \pi F)]$$

where “ c ” is the speed of light (3×10^8 m/sec) and F is the DTV channel center frequency (in Hz). If a logarithmic conversion factor is desired, then the following equation can be applied:

$$K_{EV} = 20 \cdot \text{LOG}[c / (2 \pi F)] = 20 \cdot \text{LOG}[300 / (2 \pi F(\text{in MHz}))] = -22 \text{ dB}\mu\text{V-dB}\mu\text{V/m}$$

Note that “ $20 \cdot \text{LOG}$ ” is used since voltage (and field strength) is the parameter in question rather than power. For CH 38 (615 MHz), K_{VE} is about -22 dB μ V-dB μ V/m. This means that the voltage at the output of a matched dipole antenna (in dB μ V) can be found by subtracting 22 dB from the field strength value (in dB μ V/m). Likewise, field strength at the input of a matched dipole antenna (in dB μ V/m) can be found by adding 22 dB to the output voltage (in dB μ V) of a matched dipole antenna. Of course, if a channel other than CH 38 is being used, a different conversion factor would be calculated and used.

The two equations described above can be combined and used to relate field strength and output power when using a calibrated dipole antenna matched to its characteristic impedance.

$$K_{EP} \text{ (in dBm)} = K_{EV} + K_{VP} = [20 * \text{LOG}[300 / (2 \pi F \text{ (in MHz)})] - 107.0] = -129.2 \text{ dBm-dB}\mu\text{V/m (for CH 38)}$$

Therefore, the field strength at the input of a matched dipole antenna can be found by taking the antenna output power (in dBm) and adding the 129.2 dBm-dB μ V/m conversion factor. That is,

$$E(\text{min}) = S1(\text{min}) + 129.2 = -84.6 \text{ dBm/6 MHz} + 129.2 = 44.6 \text{ (in dB}\mu\text{V/m)}$$

This minimum value for easily (no noise subtracting at the spectrum analyzer input) measurable field strength does *not* extend down to the FCC's required 41 dB μ V/m. However, if a *directional* antenna with gain is being used, and its gain is specified relative to a matched dipole antenna (i.e., in dBd), the final field strength value can be calculated as follows:

$$FS = E \text{ (dB}\mu\text{V/m)} - G_A(\text{dBd}) = 44.6 \text{ dB}\mu\text{V/m} - 8 \text{ dBd} = 36.6 \text{ dB}\mu\text{V/m}$$

For the best accuracy, the spectrum analyzer must have channel power measurement capability. That is, it must allow the user to adjust band power markers that provide an *integrated* average power over the entire 6 MHz DTV channel. The spectrum analyzer must also have the capability to select a resolution bandwidth between 10 kHz and 30 kHz to accurately measure the entire DTV signal, including the steep (620 kHz wide) transition regions.

APPENDIX D:

FIELD STRENGTH MEASUREMENT STEP-BY-STEP METHODOLOGY

A. For tests to determine eligibility to receive distant DTV network station signals, the tester should consult with an appropriate authority, such as Decisionmark Corporation, to determine all transmitters (whether full-power, satellite, or translator stations) that may deliver a signal of the required minimum intensity to the household. The tester should also consult with a knowledgeable authority to determine which transmitters are, at the time of the test, exempt from digital testing, and conduct an analog signal intensity test for those stations to determine if a signal of Grade B intensity is present at the location.

B. Prior to beginning DTV field testing, the test equipment should be checked and calibrated at the desired DTV channel to be tested.

- 1) Perform a self-calibration at the desired DTV channel frequency on a spectrum analyzer that is capable of making channel power measurements on a noise-like DTV signal in a 6 MHz bandwidth.
- 2) Measure and document directional horizontally-polarized receive antenna gain over an equivalent dipole (in dBd) at the desired DTV channel (center frequency), or use manufacturer's calibrated antenna gain value (in dBd), if available.
- 3) Measure and document any balun loss (in dB) at the desired DTV channel (center frequency).
- 4) Measure and document the download cable loss (in dB) at the desired DTV channel (center frequency).
- 5) Measure and document the low-noise preamplifier gain (in dB) at the desired DTV channel (center frequency).
- 6) Measure and document any other RF component losses (in dB) in the signal path, such as bandpass filters, splitters, etc., if used.
- 7) Measure and document the entire gain from the antenna *output* through the combination of cascaded download cable and preamplifier (in dB) at the desired DTV channel.
- 8) Document average noise floor power (dBm in 6 MHz) at the desired DTV channel (using same range or input attenuator setting that is used for field strength measurement).
- 9) Determine the minimum signal power that can be accurately measured (see previous section), and calculate minimum measurable DTV field strength that can be measured.

C. The following is a step-by-step procedure for measuring the field strength at a given test site location.

- 1) Determine the specific test site location where the measurements are to be made.
- 2) Park the test vehicle in a manner where multiple measurements can be made that encompass five test points (3 meters square with tests at each corner and the center).
- 3) Verify that there are no obstructions above the truck (trees, power lines, etc.) that would hamper measurements, and place safety cones at appropriate locations around the vehicle.
- 4) Record test site location information

- a. Date and time of day of the field strength measurements.
- b. GPS coordinates for latitude and longitude (including a street address, if possible).
- c. Distance (in miles) from test site to each DTV transmitter.
- d. Direction (in degrees with respect to due north) from test site to DTV transmitter.
- e. Terrain description (flat, hilly, mountainous, etc.)
- f. Height (elevation above sea level in feet)
- g. Vegetation (trees, farmland, etc.)
- h. Buildings and other obstacles (bridges, water towers, etc.)
- i. Weather (clear, cloudy, rain, snow, windy, etc.)
- 5) Raise vehicle antenna to either 30' AGL (for a two-story building measurement) or to 20' AGL (for a one-story measurement).
- 6) Perform a spectrum analyzer self-calibration.
- 7) Orient the directional antenna (main beam pattern) towards the transmitter, rotating it for maximum DTV field strength (i.e., maximum average DTV signal power in 6 MHz on the spectrum analyzer).
 - a. If the maximum field strength is determined to be from a direction significantly different (i.e., more than 25 degrees in either direction) from that towards the DTV transmitter, then make two measurements.
 - b. The first measurement reflects the DTV field strength with the antenna pointing towards the direction that provides the maximum signal level.
 - c. The second measurement reflects the DTV field strength with the antenna pointing directly towards the DTV transmitter.
- 8) Measure and record the total average power (dBm in 6 MHz) of the received DTV signal.
- 9) Calculate and record the DTV field strength (using the equations in the previous section) for each DTV measurement.
- 10) Repeat for the remaining measurement locations at the given test site.
- 11) Calculate and record the *median* field strength of the multiple (5) DTV field strength measurements.

D. After completing field strength testing, the following information should be documented as a summary of the testing.

- 1) Create a list of the *calibrated* equipment used in the field strength survey.
 - a. Manufacturer.
 - b. Model number (i.e., type).
 - c. Serial number & rated accuracy.
 - d. Date of its most recent calibration by the manufacturer or by a laboratory.
 - e. Any further details of non-standard equipment that is used.
- 2) Detailed description of test vehicle system.
 - a. Antenna gain
 - b. Dipole factor for each DTV channel (dBuV/m – dBm, which includes both field strength to voltage conversion and voltage to power conversion)
 - c. Net vehicle gain, which includes both downlead cable loss and preamplifier gain (in dB)

- 3) All necessary information that describes each DTV transmitter facility.
 - a. Channel number and center frequency (in MHz).
 - b. Geographical coordinates of transmitter site (latitude and longitude).
 - c. Rated and actual transmitter power output (TPO, in dBkW)
 - d. Measured transmission line loss (in dB)
 - e. Antenna power gain compared to dipole (in dBd)
 - f. Antenna height above ground level (AGL, in feet).
 - g. Antenna height above sea level (ASL, in feet)
 - h. Antenna height above average terrain (HAAT, in feet)
 - i. Antenna horizontal and vertical plane patterns of transmitting antenna
 - j. Calculated effective radiated power (ERP, in dBk)
- 4) Topographical map indicating location of each DTV transmitter and each test site.
- 5) Terrain profiles between the DTV transmitter and each test site.
- 6) Tables of the field strength measurements with the following information for each field test site:
 - a. Distance (in miles) and direction (in degrees with respect to due north) from field test site to DTV transmitter.
 - b. Antenna elevation (in feet) above ground level (AGL) at measuring location.
 - c. Date, time of day, and weather.
 - d. Median field strength (in dBuV/m) for multiple test site measurements, including notes on any signal level variations during the testing.
 - e. Notes describing each measurement test site locale.

Exhibit E

Qualifications of the Firm **Meintel, Sgrignoli, & Wallace**

William Meintel

Mr. Meintel holds a degree in Electrical Engineering and has 36 years experience in the communications field. After graduation, he was employed by the Federal Communications Commission, first as a field engineer and then in the Mass Media Bureau's Policy and Rules Division. While in Policy and Rules, he served as the division's computer expert and directed the development of several major computer modeling projects related to spectrum utilization and planning.

He entered private practice in 1989, and has been heavily involved in technical consulting, computer modeling and spectrum planning for the broadcast industry. In April 2005, Mr. Meintel merged his consulting practice into the firm Meintel, Sgrignoli, & Wallace.

Mr. Meintel co-authored a report for the NAB on spectrum requirements for Digital Audio Broadcasting (DAB), created a plan for independent television broadcasting for Romania and has been extensively involved in spectrum planning for digital television (DTV) in both the US and internationally.

Mr. Meintel wrote the coverage and interference analysis software utilized to develop the DTV Table Of Allotments and is well versed in the application of Longley-Rice and other propagation models. Mr. Meintel also wrote the software for the FCC's processing of DTV applications utilizing OET-69. He is a member of IEEE and Tau Beta Pi.

Gary Sgrignoli:

Gary Sgrignoli is a principal engineer and founder of Meintel, Sgrignoli, & Wallace. Mr. Sgrignoli received his BSEE and MSEE degrees from the University of Illinois in 1975 and 1977, respectively. He was a Principal Engineer and Consulting Engineer at Zenith Electronics Corporation from 1977 until February 2004, when he left for private practice.

Mr. Sgrignoli has worked in the research, development, and design area on television "ghost" canceling, cable TV scrambling, and cable TV two-way data systems before turning to digital television transmission systems. Since 1991, he has been extensively involved in the 8-VSB transmission system design, its prototype implementation, and lab and field tests with Zenith and the Grand Alliance.

He holds 35 U.S. patents, including some that are related to digital television transmission and the 8-VSB transmission system. Mr. Sgrignoli is a recipient of the IEEE Matti S. Suikola award presented by the IEEE Broadcast Technology Society.

He was involved with the DTV Station Project in Washington DC, helping to develop DTV RF test plans. He has also been involved with numerous television broadcast stations around the country, training them for DTV field testing and data analysis, and participated in numerous DTV over-the-air demonstrations with the Grand Alliance and the ATSC, both in the U.S. and abroad. In addition to publishing technical papers and giving presentations at various conferences, he has given many of his VSB transmission system tutorials around the country. He is a member of IEEE.

Dennis Wallace:

Dennis Wallace has an extensive background in Digital Television Systems. Mr. Wallace managed all the Laboratory RF Testing of the Grand Alliance ATSC HDTV System, having served as the RF Systems Engineer at the Advanced Television Test Center (ATTC). He managed test plans, configurations, and operations for Grand Alliance Testing and several Datacasting Systems. Prior to joining ATTC, he held positions in Field Operations Engineering, Applications Engineering, and was Product Manager for two Television transmitter manufacturers.

In July 1997, Dennis founded Wallace & Associates a broadcast engineering and consulting firm specializing in Digital Television, RF Propagation Measurements, Spectrum Policy issues, and Technical Consulting. His clients include major broadcast groups, The DTV Station Project, ATTC, Trade Associations, and both Professional and Consumer Electronics Manufacturers. In April of 2005 Wallace & Associates was merged into the firm of Meintel, Sgrignoli, & Wallace.

He has worked on the Broadcast side of the fence, as well, holding Chief Engineer and Operations Manager, positions with both Radio and Television Stations.

In 1999, Mr. Wallace was awarded the prestigious Matti S. Suikola award by the IEEE Broadcast Technology Society.

Mr. Wallace is a Certified Broadcast Television Engineer by the Society of Broadcast Engineers. He is also a member of the IEEE Broadcast Technology Society, SMPTE, an Associate member of the Federal Communications Bar Association, and is active on several industry standards committees and the ATSC.